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PROJECT SQUID

TECHNICAL MEMORANDUM No. CAL-20

SUGGESTED FORMS FOR AIR DUCT MOTORS
UTILIZING INTERMITTENT COMBUSTION

PART IV INTERMITTENT COMBUSTION EXPERIMENTS

By

JOSEPH LOGAN, JR.
O. B. FINAMORE

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CORNELL AERONAUTICAL LABORATORY, INC.
BUFFALO, NEW YORK

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Buffalo, New York

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ABSTRACT

Preliminary experiments conducted with valveless jet models have verified the theoretical conclusion that intermittent combustion processes could be sustained without the use of flapper valves. Experiments with a dynajet also indicate that the use of flapper valves may contribute to pulse jet inefficiency.

These experiments, combined with previous observations of rough and explosive burning phenomena indicate that this intermittent burning may be a very stable process in certain types of tubes.

INTRODUCTION

Previous memoranda in the series[1,2] considered the possibility of developing new forms of valveless intermittent combustion devices based primarily upon the assumption that flapper valves were not required to sustain intermittent combustion. This paper describes the experimental verification of this possibility which may have great significance for future developments in this field of jet propulsion.

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VALVELESS JET INVESTIGATIONS

Small jets were constructed as indicated in Figures 1a and 2. Air and fuel were injected directly into the combustion chamber. After initial ignition, intermittent burning was immediately established and operation could be maintained without a spark. Ease of starting was indicated. Operation was stable at approximately 350 cycles although expected operating frequency estimated by comparison with the dynajet was of the order of 600 cycles per second.

The combustion chamber of a dynajet was modified in a similar manner, Figures 1b, 3 and 4, and operation similar to that with valves was obtained. The plate used to close the flapper valve inlet ports is shown in Figure 4.

Measurements indicated that operation was stable at frequencies of approximately 150 and 300 cycles. The frequency of operation could be varied by changing the rate of fuel flow. Preliminary measurements indicated that maximum thrust and minimum fuel flow were obtained at the lower frequency.

In another series of experiments the flapper valve bank of a 6" x 4" pulse jet[4] was replaced by a plate, Figures 1c, 5, and 6, and air and fuel were injected directly into the combustion chamber. Intermittent operation was obtained similar to that observed with the small jets. Once the intermittent combustion process was established, the jet formed appeared to be extremely stable. Operation could be sustained even with the tailpipe partly closed.

THE STABILITY OF THE INTERMITTENT BURNING PROCESS

Experimental and theoretical studies of flame propagation in open and closed tubes[3,8,9,10] have indicated that as soon as waves generated during the combustion process are reflected from the ends of the tube and reach the flame front, acceleration or retardation of the flame front occurs. It appears then that any burning process in a tube is essentially an oscillatory process involving rapid acceleration and retardation of the flame front.

Experiments with valve operated pulse jets have indicated that burning may not be completely extinguished prior to ignition of the fresh mixture[5]. The strong expansion waves, developed during the combustion process and through reflection, may tend only to weaken, the burning process prior to air inflow[7]. If strong compression and expansion waves appreciably influence the course of combustion in pulse jets, similar types of burning should be observed in half-open tubes with continuous air and fuel injection provided similar strong waves are created in the combustion process. It is believed, therefore, that this intermittent burning observed in the valveless jet tube is a basically stable process.

The rough burning phenomena observed in burners of gas turbines and ram jets under certain conditions may be a similar stable process. It is expected that combustion chamber design will influence the stability of the intermittent burning. In the valveless jet investigations using the 6" x 4" jet it was observed that continuous burning could be obtained by controlling the rate of air and fuel flow although the intermittent combustion phenomenon was the easier to achieve.

Under certain conditions intermittent combustion has been observed in straight tubes. N. P. Bailey[6] describes an explosive burning obtained using hydrogen as a fuel. The burning was described as a series of explosives at the resonant frequency of the tube - a "violently noisy form of combustion". The combustion could be made quiet and orderly by changing the position of the fuel injector. In summarizing Bailey noted that "this instability could have occurred because the operation was inherently unstable". In these experiments the hydrogen was supplied at high pressure and an orifice pressure drop greater than the critical value was used to avoid any chance of fluctuations in fuel-supply rate.

Similar noisy combustion was noted using the 6" x 4" jet tube. This type of burning appeared to be very inefficient since very little stable jet formation was observed. However, by properly adjusting the fuel supply smooth pulsating operation was obtained with strong, stable jet formation. The method of injecting fuel and air did not appear to affect operation to any appreciable extent in the preliminary experiments.

The frequency with which various types of rough burning and explosive burning phenomena are noted in the literature, in conjunction with the previously described experiments, indicates that an intermittent combustion process may be particularly stable in certain tube forms.

CONCLUSIONS

Preliminary experiments with valveless pulse jets have indicated that intermittent burning can be sustained in tubes even though continuous air and fuel injection take place. These experiments indicate also that maximum thrust and specific impulse values are not necessarily obtained at the frequency at which the same jet would operate with flapper valves.

These preliminary experiments appear to have great significance for future developments in this field of jet propulsion.

PLANS FOR FUTURE WORK

Small valveless jet models are being constructed[1,3]. Experiments are planned to determine the possibilities of obtaining high specific impulse values with these engines[3,11] The possibility of conducting these experiments under SQUID sponsership has not as yet been ascertained.

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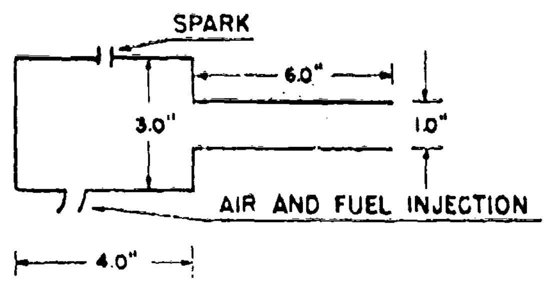
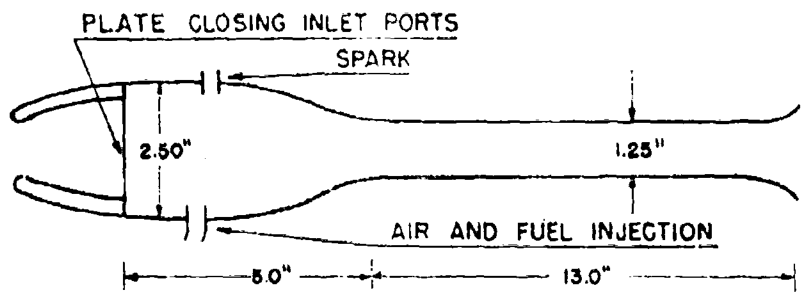
The writers wish to thank Mr. W. Lenz who modified and constructed the models used in this investigation and Dr. J. V. Foa, Mr. G. Rudinger and Dr. G. Markstein for valuable suggestions during the preparation of this paper.

VALVELESS JET FORMS INVESTIGATED



(a)



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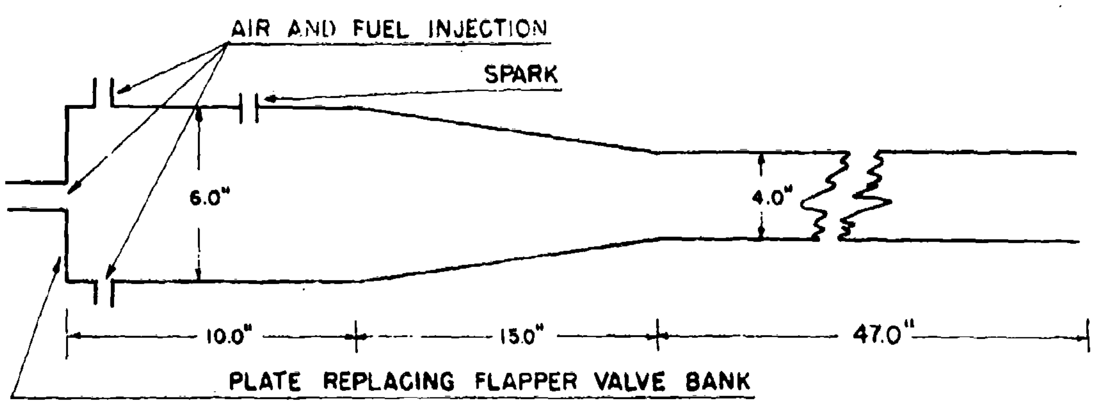
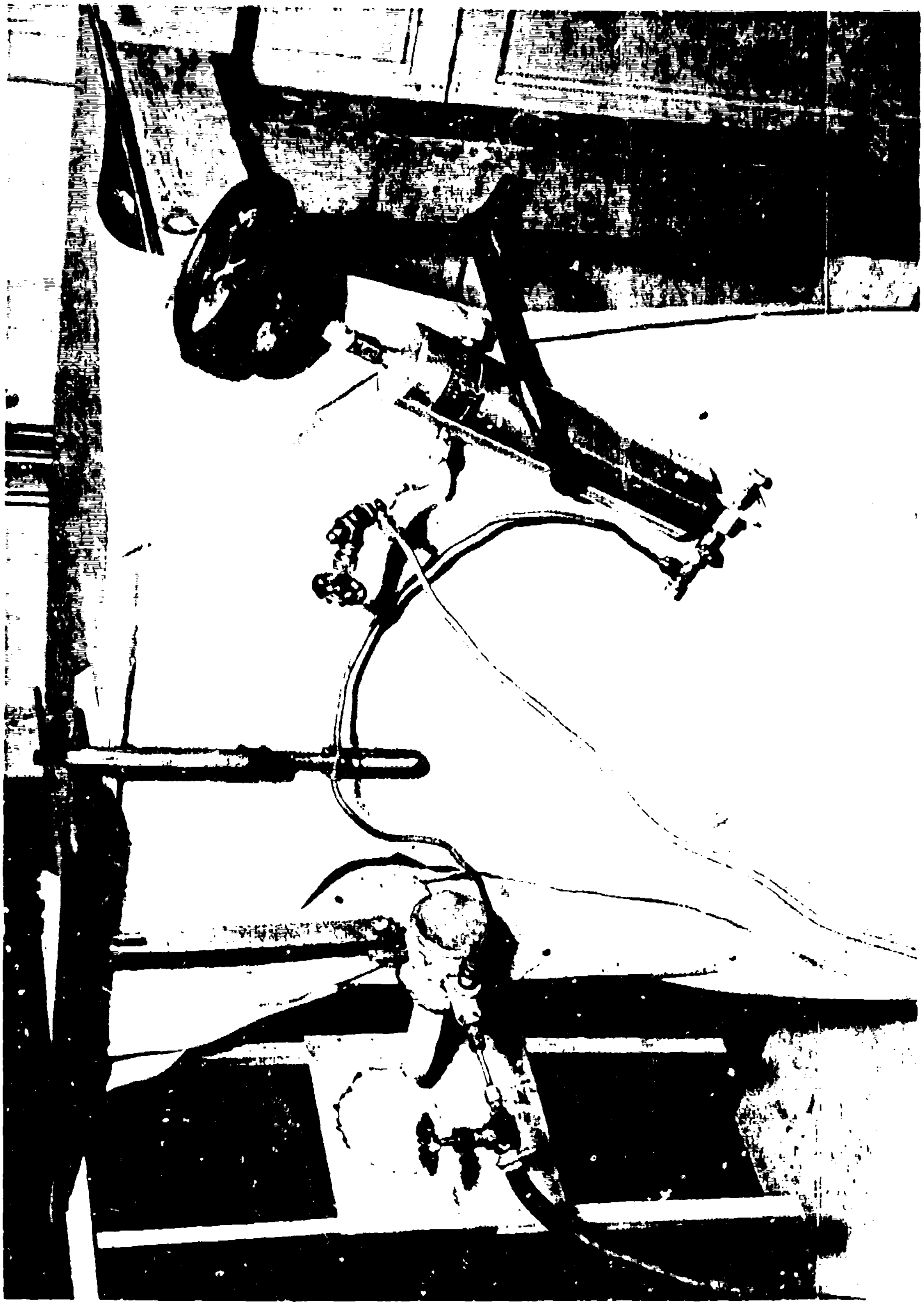
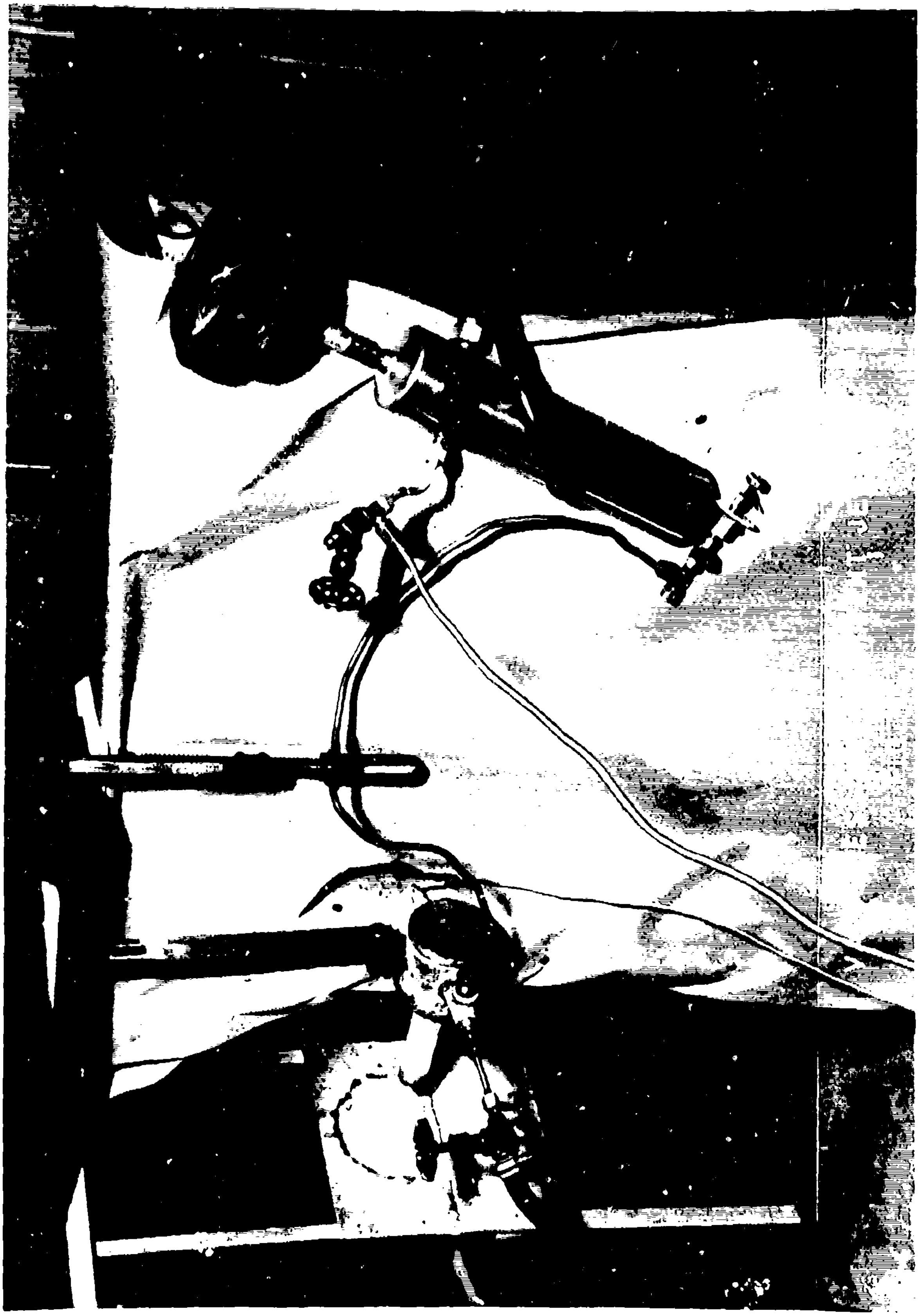
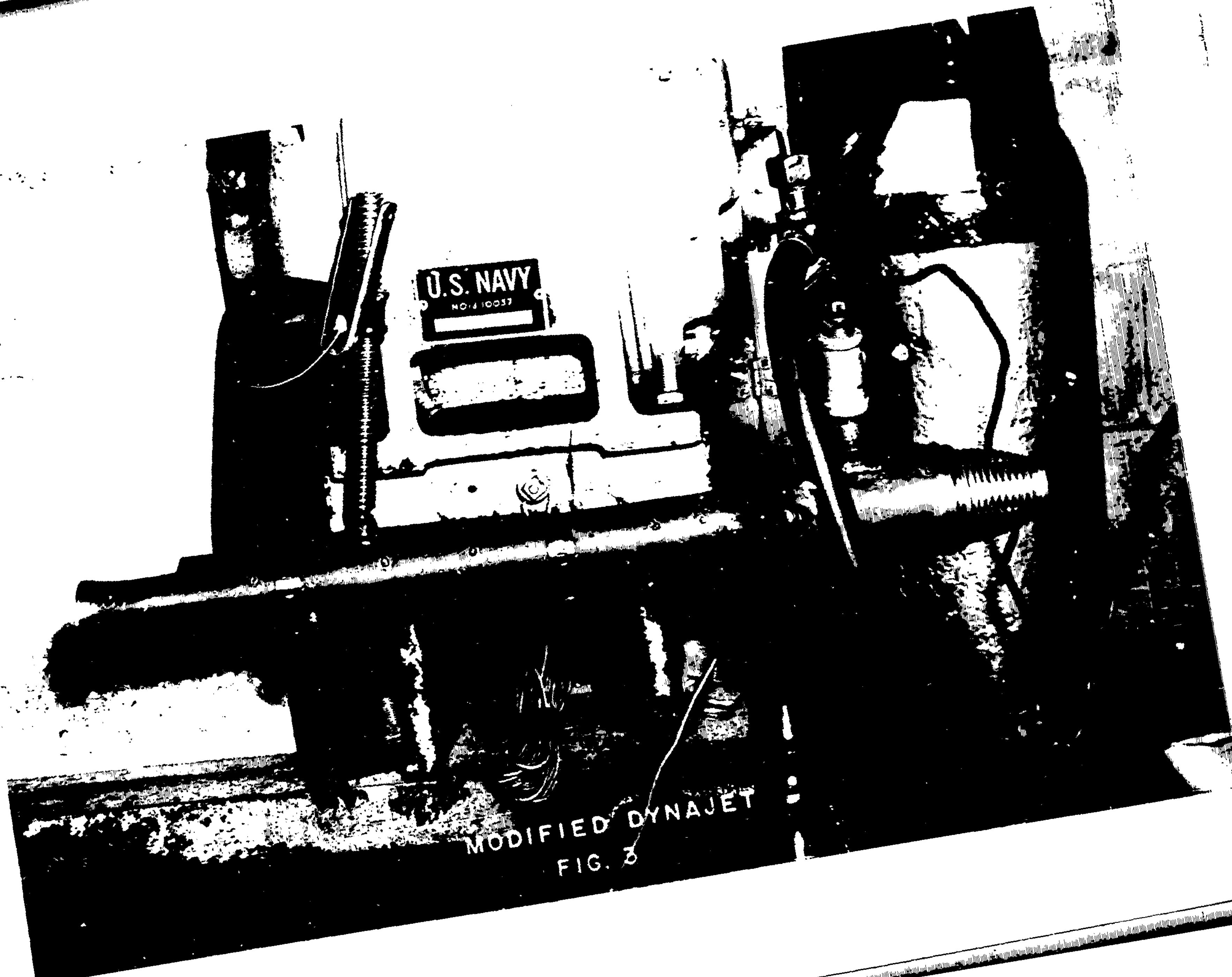


(c)

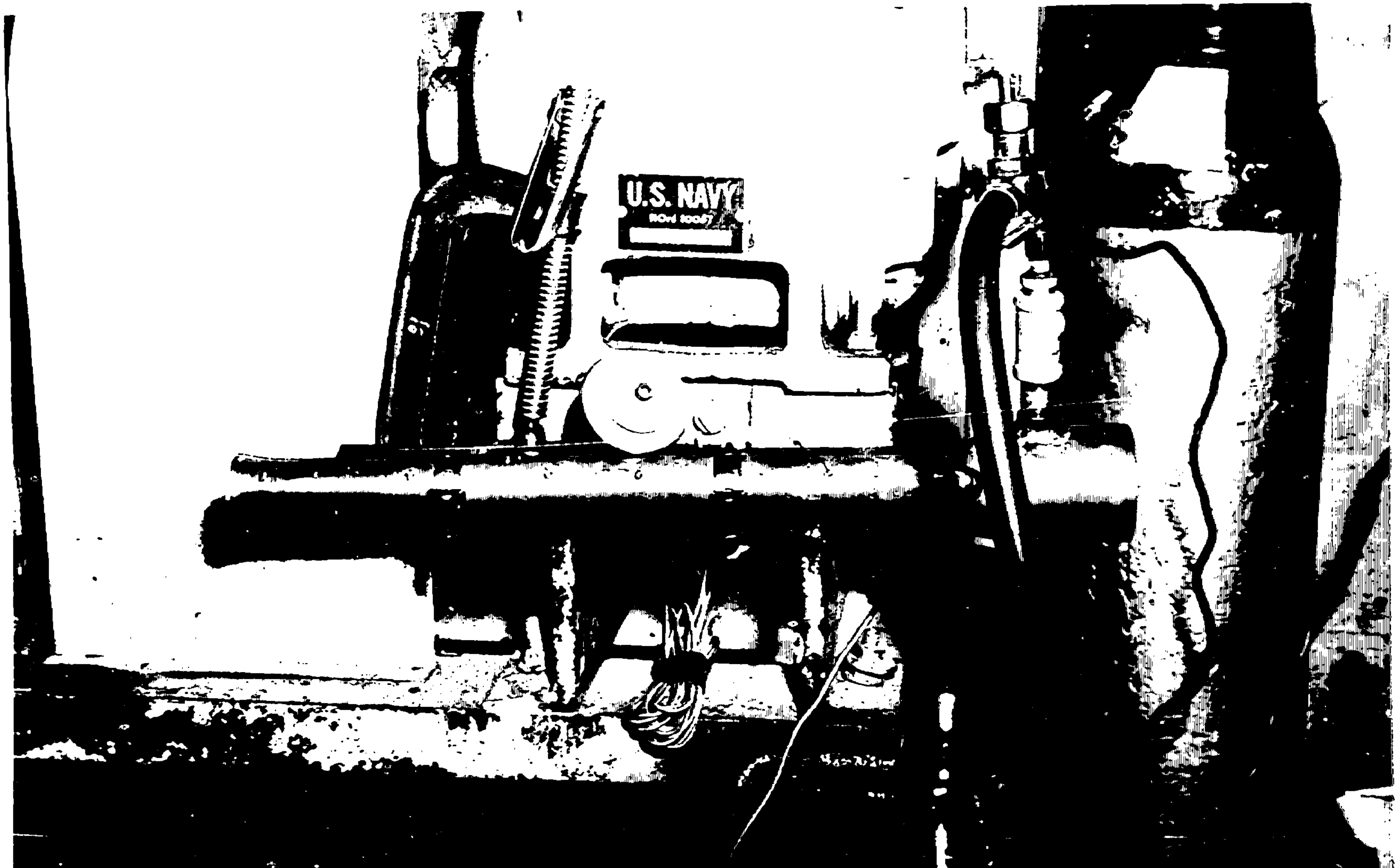
Fig. 1





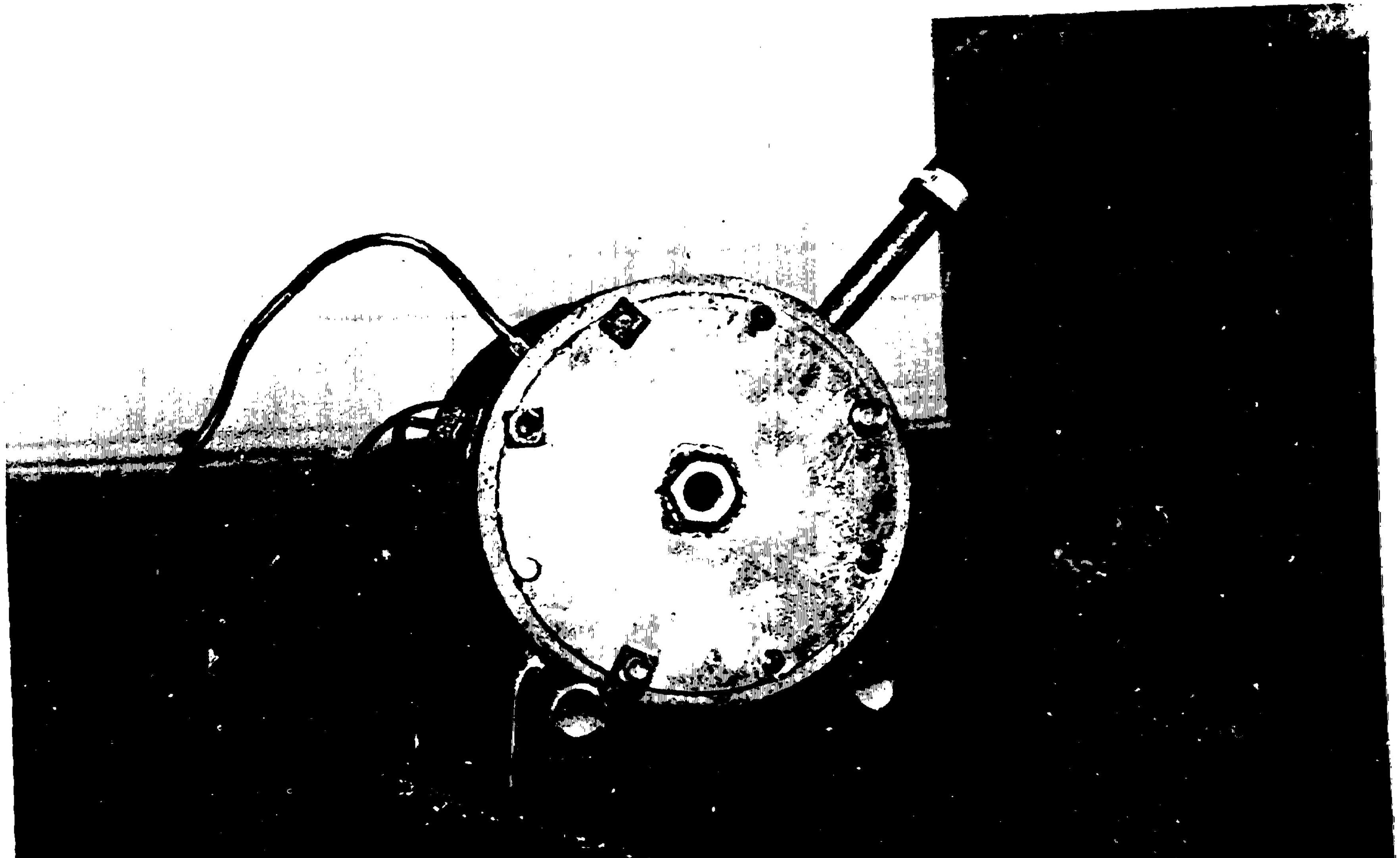


MODIFIED DYNAJET
FIG. 3



MODIFIED DYNAJET SHOWING
PLATE REPLACING SPRING VALVES
FIG. 4


NO
SMOKING
JET



MODIFIED 6" X 4" PULSE JET SHOWING PLATE
REPLACING FLAPPER VALVE BANK
FIG. 6